RODENTS AND SHREWS IN UNGRAZED TALLGRASS PRAIRIE MANIPULATED BY FIRE

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Abstract. Natural prairie was a mosaic of patches of depths of plant litter due to topoedaphic conditions and to spatial-temporal variation in fire and grazing. Such variation in litter depth undoubtedly influenced the distribution and abundance of small mammals. To examine this issue, small mammals were censused and plant litter depth was measured during autumn from 1981 to 1984 on the Konza Prairie Research Natural Area near Manhattan, Kansas. Five to 11 sites subjected to fire at different times from 1967 to 1984 were sampled during each of the four years of the study. Relative densities of deer mice (*Peromyscus maniculatus*) were negatively correlated to litter depth, whereas relative densities of Elliot's short-tailed shrews (*Blarina hylophaga*) and western harvest mice (*Reithrodontomys megalotis*) were positively correlated to the depth of plant litter. White-footed mice (*Peromyscus leucopus*), typically found in wooded and brushy habitats, were captured in prairie sites, but no significant association with plant litter was evident. Although prairie voles (*Microtus ochrogaster*) were expected to be positively associated with litter, no significant relationship was found for 1982 (the only year with sufficiently high densities to test for a possible pattern).

Key Words. small mammals, plant litter, tallgrass prairie, fire, rodents, shrews, Kansas

INTRODUCTION

General observations in tallgrass and mixed grass prairies reveal dramatic spatial and temporal variation in plant litter depth as the result of grazing by large ungulates, occurrence of fire, and topoedaphic conditions. Presettlement prairie would have been a mosaic of habitat patches with different depths of litter brought about by spatial variation in grazing by bison (*Bison bison*), occurrence and intensity of natural and anthropogenic fires, and topoedaphic conditions. For many species of grassland animals, suitability of a habitat patch undoubtedly would have been influenced by the depth of the litter layer. For example, Henslow's sparrows (*Ammodramus henslowii*) require a well-developed layer of standing dead vegetation in their territories (Zimmerman 1988). Further, use of local areas of prairie by deer mice (*Peromyscus maniculatus*), as censused by use of individual trap stations, is negatively related to the depth of litter (Kaufman *et al.* 1988).

To examine possible relationships between litter architecture and use of prairie by rodents and shrews, small mammals were censused and plant litter depth was measured in watersheds with different fire histories on the Konza Prairie Research Natural Area. Based on general habitat associations, negative relationships were expected between density and plant litter depth for some species of small mammals (e.g., the deer mouse), and positive relationships were expected for others (e.g., the prairie vole, *Microtus ochrogaster*; western harvest mouse, *Reithrodontomys megalotis*; and Elliot's short-tailed shrew, *Blarina hylophaga*).

The objective of this research was to test these predictions as well as examine the relationships of plant litter depth to species richness and diversity of the assemblages of small mammals found in different habitats in the tallgrass prairie of the Flint Hills region of eastern Kansas. An additional objective was to test for a possible relationship between litter and use of prairie by the white-footed mouse (*Peromyscus leucopus*), which is typically a woodland rodent that is caught only infrequently in prairie sites.

STUDY AREA AND METHODS

This study was conducted on the Konza Prairie Research Natural Area which is located south of Manhattan in Riley and Geary counties, Kansas. This 3,487-ha site is characterized by steep-sided hills with flat-topped ridges dissected by ravines that create lowland prairie. The area was grazed by domestic livestock for over 100 years before establishment of the Konza Prairie Research Natural Area in 1971-1977, but no cattle have been grazed on these research sites since 1977. Vegetation is typical of tallgrass prairie of the Flint Hills which is dominated by big bluestem (*Andropogon gerardii* Vitman), indiangrass [*Sorghastrum nutans* (L.) Nash], and little bluestem (*Andropogon scoparius* Michx). Several other grasses, numerous forbs, and some shrubs occur commonly in prairie habitats on Konza Prairie (Freeman and Hulbert 1985). Additional information on habitat types as well as mammals found on the Konza Prairie is given in Finck *et al.* (1986) and Kaufman *et al.* (1988).

Small mammals and litter conditions were studied along permanent trap lines in 10 watersheds in 1981, 11 in 1982, 5 in 1983, and 10 in 1984. Time since last fire for each watershed in each year is summarized in Table 1. The first year after fire indicates that the watershed was sampled in autumn after a spring fire approximately six months earlier, the second year in autumn approximately 18 months after fire, and so forth.

Table 1. Years since last fire for each watershed sampled in each year.

Watershed	1981	1982	1983	1984
	years			
1D	1	1	—	1
10A	1	2	3	4
4F	1	2	—	4
4G	2	3	—	1
4B	3	4	1	2
4D	4	1	2	3
20B	9	10	11	12
NUD	14	15	—	—
N1B	14	15	—	17
N4D	14	15	16	17
NUB	—	3	—	5

Small mammals were sampled in each watershed in each year using two permanent 20-station census lines with a 15 m interstation distance. These lines were placed so that similar mixtures of upland, hillside, and lowland prairie were trapped in each watershed. Traps were set and checked on each line for four consecutive days during October in each of the four years. Two large Sherman live traps (7.6 X 8.9 X 22.9 cm) were set within 1 m of each station marker. Bait was a mixture of peanut butter and rolled oats molded into a small ball and suspended in weighing paper from the back door of the trap. Polyester fiberfill was used as

nesting material in each trap. Small mammals were toe-clipped and released at the point of capture. Relative densities of small mammals were calculated as the average number of unique individuals caught per trap line in each watershed in each year.

Litter depth was indexed at 20 points around each trap station during November of each year. This was done by placing a 2-m

Table 2. Relative density of small mammals (numbers/trap line) during 1981-1984.

Species	1981[1]	1982[1]	1983[1]	1984[1]
		numbers/trap line		
Deer mouse	6.1	5.0	3.2	4.6
Elliot's short-tailed shrew	2.9	5.8	3.4	3.9
Western harvst mouse	5.2	6.3	0.7	0.1
White-footed mouse	3.3	2.3	0.4	1.8
Prairie vole	1.2	5.9	0.2	0.6
Thirteen-lined ground squirrel	0.3	0.6	2.0	0.6
Cotton rat	3.8	0.5	0.2	0.0
Hispid pocket mouse	0.1	0.1	0.4	0.0
Plains harvest mouse	0.6	0.3	0.0	0.0
House mouse	0.3	0.1	0.0	0.0
Meadow jumping mouse	0.1	0.0	0.0	0.0
Southern bog lemming	0.0	0.8	0.0	0.0
Least shrew	0.0	0.2	0.0	0.0

[1]Numbers of trap lines/year 2343 20 in 1981, 22 in 1982, 10 in 1983, and 20 in 1984.

length of metal conduit (18 mm in diameter) straight down through the vegetation and recording the presence of litter touching the pole at a height of 0-1 cm (height class 1), 1-10 cm (height class 2), and above 10 cm (height class 3). The 20 points around each station were on four transects radiating out from the station marker at approximately 45° from the axis of the trap line. The sampling points along each of the four transects were chosen by stepping from the station marker to a point approximately 1.5 m from the station marker and placing the conduit directly down through the vegetation. Point 2 was chosen by stepping about 1.5 m from point 1; this procedure was repeated for the remaining points along each transect. Data from the 20 points around each station along the two trap lines in each watershed (a total of 40 stations) were used to calculate the average percent occurrence of plant litter in the three height classes for each watershed in each year. A summary index of litter depth was created by adding the percent occurrences for all three height classes; this is the litter index used for tests of relationships of small mammals to litter reported in this paper.

In addition to litter height, the presence of vegetation or litter under the conduit was also recorded. Subtraction of the percent occurrence of both litter and vegetation from 100% yielded an index to the percent of bare surface in each watershed.

RESULTS

Thirteen species of small mammals (11 of rodents and 2 of shrews) were recorded during the four years of the study with 11 species caught in 1981, 12 in 1982, 8 in 1983, and 6 in 1984. The average number of small mammals caught per trap line was 19.1 in 1981, 22.5 in 1982, 8.9 in 1983, and 10.0 in 1984. The thirteen species caught were the deer mouse, Elliot's short-tailed shrew, western harvest mouse, white-footed mouse, prairie vole,
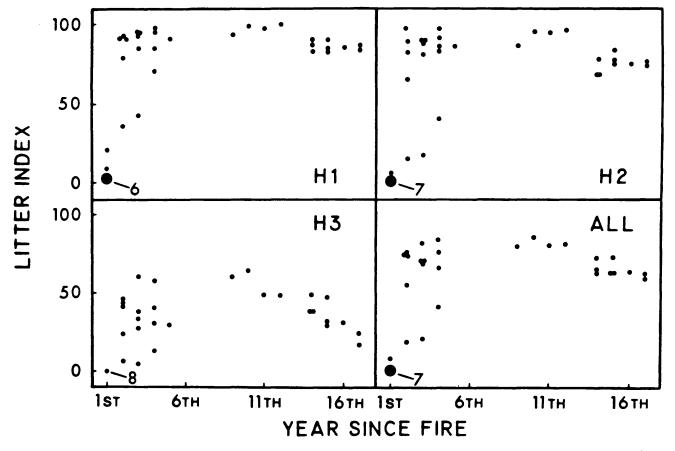

FIG. 1. Relationships between percent occurrence of litter and year since fire for height classes of 0-1 cm (H1), 1-10 cm (H2), above 10 cm (H3), and sum of H1, H2, and H3 (ALL; y-axis values should be multiplied by three for ALL). Values plotted for first year (1st) are for autumn during the first year after an experimental spring fire and so forth. Numbers associated with small and large dots indicate the number of sample points that are encompassed by the area of the dot.
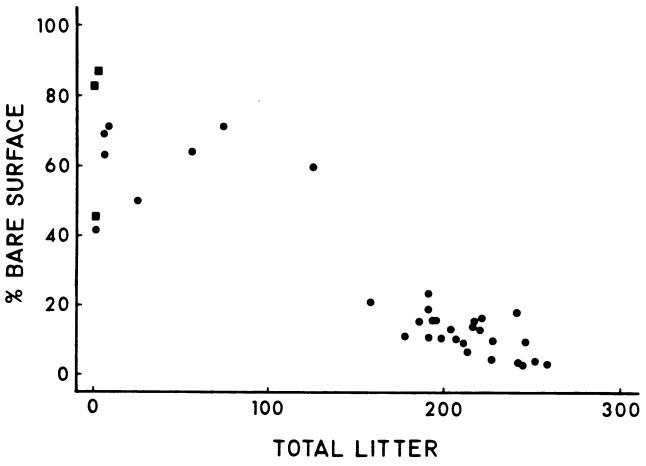
FIG. 2. Relationship between percent bare surface and total litter. Squares are for the annually burned treatment (same site sampled in 1981, 1982, and 1984).

thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), cotton rat (*Sigmodon hispidus*), hispid pocket mouse (*Chaetodipus hispidus*), plains harvest mouse (*Reithrodontomys montanus*), house mouse (*Mus musculus*), meadow jumping mouse (*Zapus hudsonius*), southern bog lemming (*Synaptomys cooperi*), and least shrew (*Cryptotis parva*). Relative densities of each of these species are summarized by year in Table 2.

Changes in percent occurrence of plant litter with time since fire are summarized in Figure 1. The lowest values for each index occurred during the first autumn after experimental spring fires with the major change between the first and second year following a fire. The lowest values for the second, third, and fourth years after fire were all recorded during 1981 and were probably due to a small amount of new litter added following the low production of plant biomass in 1980 (Abrams et al. 1986). As expected, the amount of bare soil surface decreased as the amount of litter increased (r = -0.92, d.f. = 34, P <0.001; Figure 2).

No significant pattern was evident between numbers of small mammals caught per trap line and litter depth (r = -0.23, d.f. = 34, P > 0.10; Figure 3). This lack of a significant relationship remained when all sites in the first year after fire were excluded from the analysis (r = -0.01, d.f. = 26, P > 0.10). As with assemblage abundance, no other assemblage characteristic was correlated with litter depth [species richness (number of species): r = -0.04, d.f. = 34, P > 0.10; species diversity (Shannon-Wiener H'): r = -0.01, d.f. = 34, P > 0.10; evenness (Shannon-Wiener J): r = -0.06, d.f. = 34, P > 0.10]. Exclusion of all sites in the first year after fire (the eight sites with the lowest litter depth) did not alter the lack of relationships of species richness, diversity, and evenness to litter depth (P > 0.10 in all cases).

Relative densities of deer mice were negatively related to plant litter (r = -0.70, d.f. = 34, P < 0.001; Figure 3). This general relationship remained after exclusion of the eight samples taken from watersheds in the first year after fire (r = -0.45, d.f. = 26, P < 0.05).

In contrast to the deer mice, autumnal densities of Elliot's short-tailed shrews were positively correlated to the depth of plant litter (r = 0.42, d.f. = 34, P < 0.01; Figure 3). The positive relationship was strengthened by exclusion of all samples collected from watersheds in the first year after experimental spring fire (r = 0.62, d.f. = 26, P < 0.01).

Western harvest mice were abundant in 1981 and 1982, but densities in 1983 and 1984 were too low for analysis. For 1981 and 1982, relative densities were positively correlated with litter depth (r = 0.48, d.f. = 19, P < 0.05; Figure 3). With removal from the analysis of samples from watersheds in the first year after fire, no significant relationship remained between relative density of western harvest mice and litter depth (r = 0.14, d.f. = 14, P > 0.10).

Although prairie voles were moderately abundant in 1982, density was not correlated to litter depth (r = -0.33, d.f. = 9, P > 0.10). Removal of the sites in the first year after fire did not alter this basic finding (r = -0.40, d.f. = 7, P > 0.10). The relationship between relative density of prairie voles and depth of plant litter could not be tested using data from 1981, 1983, and 1984 due to the low density of voles.

Density of white-footed mice was highly variable among watersheds and years, but density was not correlated to depth of plant litter (r = -0.21, d.f. = 29, P > 0.10 with 1983 data excluded due to low densities). When the sites in the first year after fire
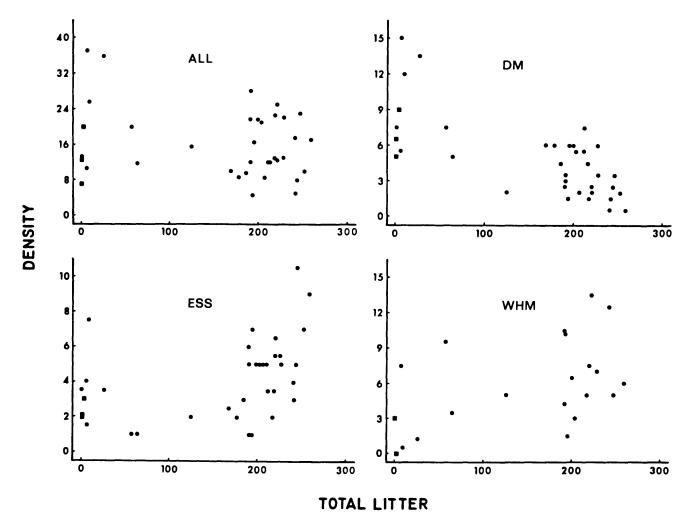
FIG. 3. Relationships between relative density (individuals/trap line) and litter depth for all species of small mammals combined (ALL), deer mice (DM), Elliot's short-tailed shrews (ESS), and western harvest mice (WHM, only 1981 and 1982). Squares are for the annually burned watershed.

were excluded, however, the negative relationship between relative density and litter depth approached significance (r = -0.35, d.f. = 22, 0.10 > P > 0.05).

DISCUSSION

None of the characteristics of assemblages of small mammals (abundance, richness, diversity, and evenness) changed in any predictable manner with changes in litter depth. However, species composition changed with litter depth as indicated by the patterns of change observed for the three common grassland mammals (deer mouse, Elliot's short-tailed shrew, and western harvest mouse).

Densities of deer mice in tallgrass prairie decreased as the litter layer increased from nearly absent to more than 10 cm deep. This pattern was consistent with the high abundance of deer mice in open grasslands of the mixed grass prairie (Kaufman and Fleharty 1974). Also, use of small patches (represented by individual live trap stations) by deer mice was negatively associated with the amount of litter and positively associated with amount of bare ground and grass (Kaufman et al. 1988). Although these patterns were only correlative ones, laboratory studies indicated that deer mice selectively forage in areas with low litter (Clark 1989).

Elliot's short-tailed shrews, insectivores that forage in the litter layer, were positively associated with litter depth. These data do not suggest an upper bound to this litter depth association, but

other observations suggest that the compaction of litter may have a negative effect on this species. Additionally, density values during the first year after fire were unexpectedly high given both the positive pattern and the relative density values for treatments with deep litter. The high values during the first autumn after a spring fire may be due to the availability of invertebrate prey even though the litter architecture is probably less than optimal for short-tailed shrews.

The western harvest mouse, a species that commonly nests aboveground (Webster and Jones 1982), showed a positive correlation with litter depth. However, no significant correlation remained when samples for treatments in the first year after fire were removed from the analysis. This suggests that this small rodent (10-15 g) requires some threshold depth of litter, but is little influenced by even deeper layers of plant litter. In agreement with our general observation of densities being higher in areas with litter versus those with essentially no litter, experimental studies demonstrated that western harvest mice foraged proportionately more often in microhabitats with litter relative to microhabitats without litter than did deer mice (Clark 1989). In contrast to the positive effect of litter on densities of western harvest mice, use of the area of individual trap stations was not directly related to the depth of litter surrounding the trap stations (Kaufman et al. 1988).

Based on these limited data, prairie voles did not show the expected positive response to litter depth, although they did re-

spond favorably to the presence of litter in experimental foraging trials (Clark 1989). As a species that constructs surface runways and some aboveground nests (Tamarin 1985), perhaps, it is the presence of some minimal amount of vegetation and litter that is needed for protection and, in some cases, nest building. The failure to find a positive relationship is possibly due to the heavy foliage that has developed by autumn in areas burned about six months earlier in spring; this heavy foliage provides food and protection and may compensate for the lack of litter. Further study is needed to assess habitat requirements of this unexpectedly uncommon small mammal on Konza Prairie.

White-footed mice are typically associated with woody or brushy habitats in Kansas (Kaufman et al. 1983), and only infrequently occur in grasslands (Clark et al. 1987). Use of grassland habitats by these mice usually occurs in areas near trees or shrubs and is probably due to nocturnal foraging movements into the prairie from nest sites in wooded microhabitats. Under experimental conditions, white-footed mice foraged preferentially in microhabitats with no litter as compared to those with a moderate to heavy litter layer (Clark 1989). Therefore, the distribution of white-footed mice is probably related to the presence of tree and shrub patches and not a need for a deep layer of litter in the adjacent prairie. With continued frequent fire and subsequent removal of woody vegetation (Bragg and Hulbert 1976), white-footed mice should decline in abundance in grassland habitats on Konza Prairie.

Based on these findings and natural history characteristics of the less common rodents on Konza Prairie, negative relationships between litter depth and numbers of hispid pocket mice and thirteen-lined ground squirrels and a positive relationship between litter depth and numbers of southern bog lemmings would be expected. However, these patterns could not be examined due to low densities during these censuses.

In summary, the negative response of deer mice to litter and positive responses of Elliot's short-tailed shrews and western harvest mice were generally as expected from known habitat associations. In contrast to short-tailed shrews, however, harvest mice demonstrated no further increase in abundance after the first year's litter was in place, i.e., no relationship between density and litter with the first year after fire excluded. Laboratory studies of foraging behavior in patches with different depths of litter by deer mice and western harvest mice lend support to these correlative findings (Clark 1989). In addition, experimental work by Clark (1989) indicated a positive response of prairie voles to litter. This failure to find such an association between abundance and litter demonstrates the need for further study of the interaction of the architecture of live vegetation, standing dead vegetation, and litter in influencing habitat use by prairie voles. Fire-positive and fire-negative responses of small mammals to a spring fire in ungrazed tallgrass prairie are probably determined in large part by the removal of the litter layer. Because of the low amount of variance in autumnal density accounted for by litter depth, experimental manipulations (e.g., addition of litter to burned sites and mechanical removal of litter from unburned sites) need to be done to confirm the direct impact of litter on population levels reached by the end of the growing season in burned and unburned prairie.

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